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Discussion on the relationship between construction safety accident and time based on the correspondence analysis model

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ABSTRACT

Based on the correspondence analysis model and the method of mining the cause and time of construction accidents. Using Python crawler technology to crawl 3896 data of the causes of construction safety accidents in China Construction Safety Supervision Information System from 2012 to 2018, a contingency table of various types and times of accidents in construction safety accidents was established. By using factor analysis, the relationship between Q-factor analysis and R-factor analysis in the corresponding factor analysis model was established. The model was analyzed and optimized by a special point removal method, and the convergence of the model was strengthened. Finally, the causes of construction safety accidents in the model and the time of one day and one year were calculated and drawn in the corresponding analysis chart of the two-dimensional model. Mining the relationship between them according to their relationship in the graph based on the data collection of 3896 building safety line accidents, this paper put forward the method of mining the main causes of accidents, and used SPSS platform technology to mine the accident data. The results showed that the occurrence of electric shock and drowning was closely related to August, fire and explosion were closely related to February, and poisoning and asphyxiation were closely related to January. 5-6 a.m. was closely related to fire

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and explosion, and vehicle injury was closely related to 8-9 p.m. To put forward prevention suggestions for construction accident prevention.

Keywords：Construction safety accident；Data mining；Time distribution；Correspondence analysis

1. Introduction

At present, the development of China's construction safety accidents is very serious, and the number of casualties in construction accidents is still high[1], which has caused a devastating blow to our whole country's political economy and national property security. However, due to the continuous expansion of the production scale of the construction industry, the construction machinery and professional labor force needed in the construction production were also growing. There were still a large number of casualties and deaths in construction. Therefore, it was of great significance to excavate the deep causes of accidents and give some suggestions for accident prevention.

China's construction industry developed rapidly, and major accidents happen frequently. At present, many experts and scholars had summarized and analyzed the causes of construction safety accidents in China. For example, Peng[2] combined with China's construction accidents from 1998 to 2009, based on the gray prediction of the MATLAB platform, to give some control measures. Ding et al.[3] based on the ratio analysis method, studied the direct and indirect influences that affected China's building safety from 1991 to 2000, And comprehensively analyzed the factors of construction industry management and the technical level of the construction industry on the status and influence of construction industry safety. Wang et al.[4] studied the safety management of building construction by applying theories of building safety early warning, and then designed and established comprehensive safety management and early warning system for Chinese construction sites. Jun et al.[5] used the LEC method to identify and analyze the hidden dangers and risks of construction accidents during the construction of a construction project, and rated and evaluated the risks, and worked out the countermeasures and measures for the hidden dangers and risks of construction accidents. Yang et al.[6] proposed a gray Markov prediction method that was particularly suitable for the characteristics of construction accident management and statistical data analysis through the research and establishment of the GM (1,1) prediction model. This prediction method was widely used in 1994-2007 construction safety accident management and frequency statistics analysis. Based on this method, the construction safety accident management and frequency statistics in 2008-2009 were predicted. Jun et al.[7] established a treemap of construction accidents that could cause a large number of casualties due to the collapse of building construction templates From the three aspects of the minimum cut set, minimum diameter set, and structural importance, the important methods and ways to prevent the occurrence of building accidents were found. Zhang et al.[8] used the accident causation theory and systematic thinking method to construct a causal system model for building accidents, considered the cause of the construction accident as a whole, and identified the key accident causes. Shao et al.[9] and others used the improved principal component analysis method to construct a hierarchical index system for a comprehensive assessment of the accident situation, and explored the accident situation of the Chinese construction industry from a multi-dimensional perspective, to understand the multi-dimensional characteristics of the accident situation in China. Zhong et al.[10] first used LSSVM to perform regression analysis and modeling on various types of building construction accident models, and predicted the collapse accidents in building construction based on relevant literature. However, most of the literature did not explicitly explore the relationship and types of collapse time and accidents caused by building collapse[2-5] and did not combine the analysis of the accident model well.

Most of the above literature did not consider the law of time and the types of building accidents, and with the different spatial distribution and the occurrence points of time, there must be a certain law for the impact of accidents, Therefore, this paper collects 3896 pieces of effective accident data of China Construction Safety Supervision Information System from 2012 to 2018, and explored the relationship between building safety accidents and time based on corresponding analysis models based on these data. Optimized through factor analysis and model convergence, and then used SPSS to analyze the corresponding time of the accident type. Therefore, the accident was related to time, and the cause of the accident can be further extended and speculated. Therefore, the occurrence of the accident was linked with time, and the cause of the accident can be further deduced and some suggestions can be given on the safety of the building.

2. Establishment of Correspondence Analysis Model of Time and Causes of Building Safety Accidents

Use the corresponding analysis model to com a-pprehensively mine the sample points. First, we used the high-dimensional sequence linked list established by the analysis model and used the low-dimensional graphics (also commonly referred to as the two-dimensional corresponding analysis chart) to make it more intuitive and concise. It accurately excavated the main sample points and causes of various types in building safety accidents.

2.1 Contingency table of time and cause of building safety accidents

Let characteristic $X=\{X_1,X_2,\cdots,X_n\}$ be the sample set of the type of accidents discovered, n is the number of types of accidents; let characteristic $Y=\{Y_1,Y_2,\cdots,Y_m\}$ be the time when the type of mining safety accidents occurred. A_{ij} represents the number of times that the j-th time of the characteristic Y exists in the i-th sample, then $A_{ij}\in(0,3896)$. According to the data obtained from the analysis, a corresponding analysis contingency table can be obtained as shown in Table 1.

Table 1 Contingency table of types and times of construction accidents

Time	Accident type			
	X_1	X_2	$\cdots$	X_n
Y_1	A_{11}	A_{12}	$\cdots$	A_{1m}
Y_1	A_{21}	A_{22}	$\cdots$	A_{2m}
Y_m	A_{m1}	A_{m2}	$\cdots$	A_{mn}

2. Covariance matrix of time and causes of building safety accident types

The corresponding time analysis factor and the R-type time factor and the Q-type time factor in the model are called the corresponding accident time sample type factor and the corresponding sample analysis type factor, respectively. If the number of corresponding types of accident time far exceeds the number of sample types at the time of the accident, $n>m$, it is a type time factor and sample analysis model, otherwise it is a type time factor and sample analysis model. The relationship between them can be established directly by selecting a transition factor matrix in the corresponding analysis model. The definition of the transition factor matrix is as follows:

$$X=\left(\mathrm{x}_{ij}\right)_{n\times m}\quad(i=1,2,\cdots,n;\ j=1,2\cdots,m)\qquad(1)$$

where $$\mathrm{x}_{ij}=\frac{A_{ij}-\sum_{i=1}^{n}A_{ij}\sum_{j=1}^{m}A_{ij}\Big/\sum_{i=1}^{n}\sum_{j=1}^{m}A_{ij}}{\sqrt{\sum_{i=1}^{n}A_{ij}\sum_{j=1}^{m}A_{ij}}}$$

The covariance matrix E_R of the building safety accident time and the covariance matrix E_Q of the accident type are：

$$E_R = Z^T Z \quad (2)$$

$$E_Q = ZZ^T \quad (3)$$

The covariance matrix of a building accident that may occur at different times in the construction engineering safety system and the covariance function matrix of the type of its occurrence time in a given specific construction accident have the same non-zero function characteristics as $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_q, 0 < q \leq \min(n,m)-1$.

2.3 Factor analysis

Let F_i be the eigenvector of the accident time covariance matrix RE relative to the characteristic root λ_i, and V_i be the eigenvector of the accident type covariance matrix E_Q relative to the characteristic root i, then we can get:

$$E_R V_i = Z^T Z V_i = \lambda_i V_i \quad (4)$$

In summary, the relationship between the R-type factor analysis and the Q-type factor analysis in the corresponding analysis model was established, so that we can exchange the results of the R-type factor analysis algorithm to generate a Q-type factor analysis result. In a matrix correspondence factor analysis model, the w-dimensional cumulative inertia was defined as the sample covariance matrix and the corresponding w-dimensional cumulative characteristic roots, and the total inertia was the sum of the covariances of all cumulative characteristic roots.

The definition of total cumulative inertia was interpreted by the definition of cumulative characteristic inertia of the previous w-dimension. The definition of the percentage $sub - p_w$ is as follows.

$$p_w = \frac{\lambda_1 + \lambda_2 + \cdots + \lambda_w}{\lambda_1 + \lambda_2 + \cdots + \lambda_q} \times 100\% \quad (5)$$

When $p_w \geq 75\%$, the model convergence meets the requirements at this time, and it is reasonable to use the analysis model to analyze the correspondence between the time and the type of accident [15].

For the R-type matrix factor, the first w matrix eigenvector roots of the whole region, and the load corresponding to the matrix eigenvector of the first w matrix eigenvector root are of the form, then the matrix eigenvector of the R-type factor load is：

$$F = \begin{bmatrix} v_{11}\sqrt{\lambda_1} & v_{12}\sqrt{\lambda_2} & \cdots & v_{1g}\sqrt{\lambda_g} \\ v_{21}\sqrt{\lambda_1} & v_{22}\sqrt{\lambda_2} & \cdots & v_{2g}\sqrt{\lambda_g} \\ \cdots & \cdots & \cdots & \cdots \\ v_{m1}\sqrt{\lambda_1} & v_{m2}\sqrt{\lambda_2} & \cdots & v_{mg}\sqrt{\lambda_g} \end{bmatrix} \quad (6)$$

Where：v_{ij} is the j-th component of the feature vector $V_i, 1 \leq i \leq m, 1 \leq j \leq g$.

For Q-type eigenvectors, the first w matrix eigenvector roots in the whole region, and the matrix eigenvectors corresponding to the first w matrix eigenvector roots are:

$$E = \begin{bmatrix} u_{11}\sqrt{\lambda_1} & u_{12}\sqrt{\lambda_2} & \cdots & u_{1g}\sqrt{\lambda_g} \\ u_{21}\sqrt{\lambda_1} & u_{22}\sqrt{\lambda_2} & \cdots & u_{2g}\sqrt{\lambda_g} \\ \cdots & \cdots & \cdots & \cdots \\ u_{m1}\sqrt{\lambda_1} & u_{m2}\sqrt{\lambda_2} & \cdots & u_{mg}\sqrt{\lambda_g} \end{bmatrix} \quad (7)$$

Where: u_{ij} is the $j\text{-}th$ component of the feature vector V_i, $1 \le i \le n$, $1 \le j \le g$.

2.4 Correspondence optimization of correspondence analysis model [16]

In general, to avoid dimensional disaster, only the first two factors were selected, which was more conducive to analysis, that was, $g = 2$, then the percentage P_2 of the total inertia explained by the previous two-dimensional inertia was:

$$P_2 = \frac{\lambda_1 + \lambda_2}{\lambda_1 + \lambda_2 + \text{L} + \lambda_q} \times 100\% \quad (8)$$

At this point, if $P_2 \ge 75\%$, it means that the model had good convergence and can be drawn in a two-dimensional picture; if $P_2 < 75\%$, the convergence of the corresponding multi-dimensional analysis model was poor. At this time, we need to pay attention to selecting multiple corresponding factors to use multi-dimensional analysis to explain the convergence of the analysis graph results. Therefore, the special point exclusion method of multi-dimensional analysis can be used to optimize the results of the analysis model corresponding to multiple factors with poor convergence, and the multi-dimensional dimension can be reduced in two dimensions. The specific operation methods and steps were described in detail as follows. Remove the time of the month or day one by one and calculate the percentage of the total inertia explained by the previous two-dimensional cumulative inertia.

$$P_2' = \frac{\lambda_1 + \lambda_2}{\lambda_1 + \lambda_2 + \text{L} + \lambda_q} \times 100\% \quad (9)$$

That was to say, the percentage difference of the convergence of the total inertia before and after the elimination of special points by the total inertia accumulated by the first two-dimensional vector and the latter two-dimensional cumulative inertia was Δp, and the larger two-dimensional vector in Δp had a significant effect on the convergence of the transformation matrix, of which the first two-dimensional vector had a significant effect on the convergence of the transformation matrix.

$$\Delta p = p_2' - p_2 \quad (10)$$

The points corresponding to the larger Δp were removed.

The correspondence between the newly formed time and the contingency table of construction safety accident types was analyzed up to $P_2 \ge 75\%$. In summary, the basic flow chart of correspondence analysis was obtained, as shown in Fig. 1.

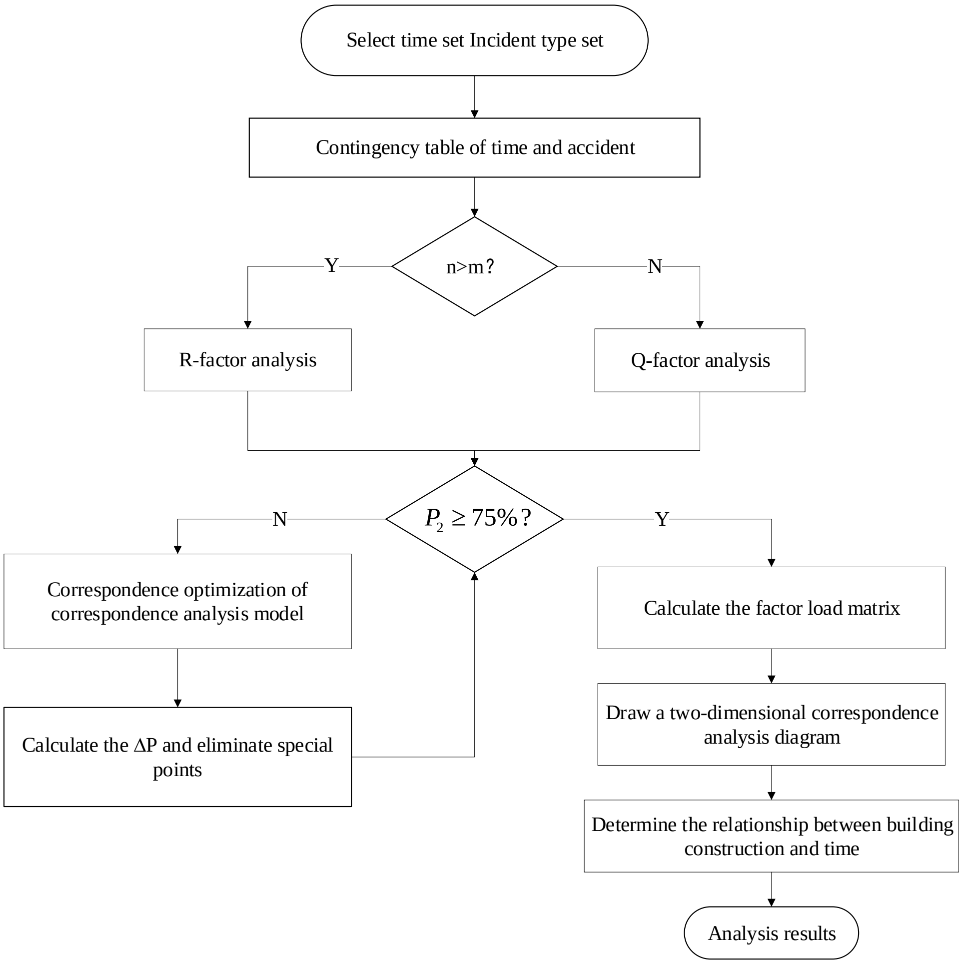

Fig.1 Correspondence analysis flow chart

3. Application example

Through the Python crawler, by collecting and integrating the web information of China Construction Safety Supervision Information system [17] (http://sgaq.mohurd.gov.cn/), after cleaning out the abnormal and duplicate data, a total of 3896 pieces of information about the types of construction safety accidents in China (excluding Hong Kong, Macao, and Taiwan) from 2012 to 2018 were obtained. Accident types were generally divided into 20 types, but because some of the accident types were special, the location was specific, such as water permeability, roof fall, blasting and so on. Or construction of relatively rare types of accidents such as boiler explosion, container explosion. Therefore, this paper was mainly based on these 3896 types and data bars, statistical analysis showed that there were 11 types of building safety accidents, such as falling high objects, electric shock, objects being hit, collapsing, other injuries, mechanical injuries, lifting injuries, poisoning, and asphyxiation, vehicle collision injuries, drowning, fire and explosion, etc. Through statistics and the establishment of a corresponding statistical analysis model, this paper excavated the relationship between accident types and occurrence time in urban building safety management.

3.1 Data analysis

From the data collected, from the time distribution of one year, as shown in Fig.2. The type of construction safety accidents mainly occurred from March to November of the year, and the main time of day was concentrated in the main working hours such as 8: 00 a.m. to 12:00 and 1: 00 p.m. to 6: 00 p.m. By analyzing the annual data of 2012 Mel 2018, it was found that the number of construction accidents remains high. Among them, high-altitude fall was the main type of accident, which occurred many times and had a large number of casualties. From the perspective of regional and spatial distribution, by dividing China into seven plates, as shown in Fig.3, it mainly occurred in East and Southwest China, while less in Northwest, Northeast, North China and Central China.

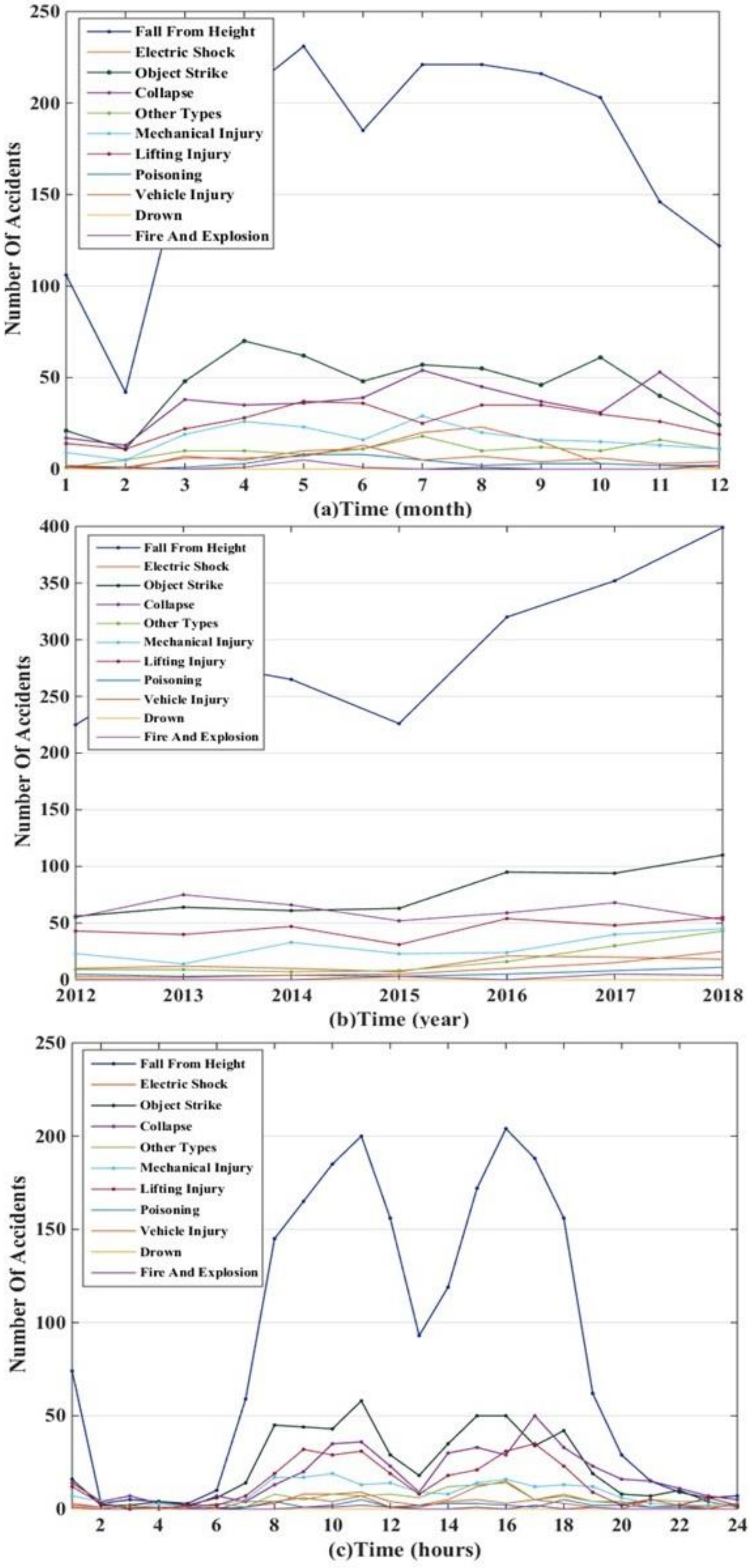

Fig. 2 Accident type and timeline chart from 2012 to 2018

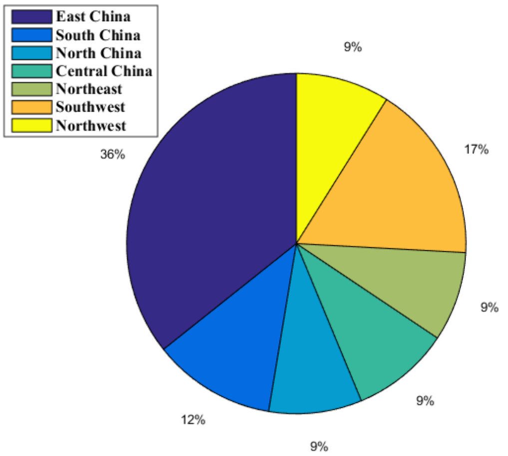

Fig.3 Accident types and regional relationship map from 2012 to 2018

3.2 Establish a contingency table of building safety accidents and time

The year was divided into 12 months as the main factor affecting the type of construction accident, which was expressed by $M_1 - M_{12}$. 24 hours a day was taken as the main factor for the type of accident at the time of the day, and recorded as

$$M = \{M_1, M_2, \cdots M_{12}\} = = \{\text{January}, \text{February}, \cdots, \text{December}\}$$

$$C = \{C_1, C_2, \cdots, C_{24}\} = \{0, 1, \cdots, 23\}$$

The accident type in 3896 pieces of data was taken as a sample of correspondence analysis,

$$N = \{N_1, N_2, \cdots N_{11}\} = \left\{\begin{array}{l}\text{Fall from height, Electric shock, Object strike,} \\ \text{Collapse, Other types, Mechanical injury,} \\ \text{Lifting injury, Poisoning and suffocation,} \\ \text{Vehicle injury, Drown, Fire and explosion}\end{array}\right\}$$

According to the establishment of the contingency table of the type of construction safety accident and the month, and the contingency table of the type of building safety accident and the period of the day, as shown in Tables 2 and 3.

Table 2 contingency table of building safety accidents and months

Month	Accident type										
	N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8	N_9	N_{10}	N_{11}
M_1	106	1	21	17	1	9	14	2	2	0	1
M_2	42	0	11	13	5	5	11	0	1	0	1
M_3	171	7	48	38	10	19	22	1	6	0	0
M_4	205	5	70	35	10	26	28	3	6	0	1
M_5	231	10	62	36	8	23	37	8	7	0	5
M_6	185	11	48	39	11	16	36	8	13	0	1
M_7	221	20	57	54	18	29	25	5	5	0	0
M_8	221	23	55	45	10	20	35	2	7	1	1
M_9	216	15	46	37	12	16	35	3	4	0	0

M_{10}	203	3	61	31	10	15	30	3	6	0	0
M_{11}	146	2	40	53	16	13	26	2	3	0	0
M_{12}	122	1	24	30	11	11	19	2	4	0	2

Table 3 Contingency table of building safety accidents and time points

Hour	Accident type										
	N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8	N_9	N_{10}	N_{11}
C_1	74	3	16	14	1	7	12	1	2	0	1
C_2	3	1	2	4	0	4	3	0	1	0	0
C_3	5	1	2	7	2	0	0	0	1	0	0
C_4	4	0	4	3	0	3	0	1	1	0	1
C_5	3	0	2	1	0	1	2	1	1	0	0
C_6	10	0	6	7	3	2	2	0	0	1	1
C_7	59	1	14	4	1	5	7	1	4	0	0
C_8	145	3	45	13	8	17	19	4	4	0	0
C_9	165	8	44	20	5	17	32	1	6	0	1
C_{10}	185	8	43	35	8	19	29	2	4	0	1
C_{11}	200	9	58	36	7	13	31	5	7	0	2
C_{12}	156	4	29	23	8	14	19	1	1	0	1
C_{13}	93	2	18	9	6	9	8	2	1	0	0
C_{14}	119	5	35	30	12	8	18	3	4	0	0
C_{15}	172	12	50	33	13	14	21	3	5	0	1
C_{16}	204	15	50	29	14	16	31	2	3	0	0
C_{17}	188	5	34	50	5	12	35	1	5	0	2
C_{18}	156	7	42	33	8	13	23	5	3	0	0
C_{19}	62	4	19	23	4	12	9	2	1	0	1
C_{20}	29	4	8	16	3	6	2	2	0	0	0
C_{21}	15	1	7	15	5	3	5	1	5	0	0
C_{22}	9	2	10	11	4	2	2	1	2	0	0
C_{23}	6	0	4	7	4	2	6	0	1	0	0
C_{24}	7	3	1	5	1	3	2	0	2	0	0

3.3 Factor Analysis of the occurrence time of Building Safety Accidents

SPSS (Statistical Product and Service Solutions) statistical analysis platform had powerful functions of data statistical analysis and calculation [18]. It can quickly complete data statistical analysis and statistical analysis management by using the command line. The text results and statistical graphics text results in statistical analysis software were displayed in the form of text characters and graphics. SPSS statistical graphic analysis software was used to calculate and analyze the data percentage of statistical chart 2Power3, and the excess matrix Z and eigenvalue （λ）, inertia interpretation percentage $\left(\lambda_k / \sum_{i=1}^{q} \lambda_i\right)$ and inertia cumulative percentage $\left(\sum_{k=1}^{g} \lambda_k / \sum_{i=1}^{q} \lambda_i\right)$ were obtained, which were shown in tables 4 and 5 respectively.

Table 4 The eigenvalue of the month, the percentage of inertia interpretation and the cumulative percentage result of inertia interpretation

Number of dimensions	Eigenvalues	Inertia interpretation percentage /%	Cumulative interpretation percentage /%
1	0.117	31.38	31.38
2	0.108	26.80	58.18
3	0.080	14.95	73.14
4	0.062	8.97	82.11
5	0.058	7.65	89.76
6	0.046	4.97	94.72
7	0.033	2.57	97.29
8	0.027	1.64	98.93
9	0.019	0.87	99.80
10	0.009	0.20	100.00

Table 5 The eigenvalue of the day, the percentage of inertia interpretation and the cumulative percentage result of inertia interpretation

Number of dimensions	Eigenvalues	Inertia interpretation percentage /%	Cumulative interpretation percentage /%
1	0.218	36.041	36.041
2	0.177	23.624	59.665
3	0.118	10.472	70.137
4	0.102	7.853	77.989
5	0.097	7.072	85.062
6	0.087	5.701	90.763
7	0.070	3.752	94.515
8	0.056	2.392	96.906
9	0.055	2.271	99.177

The cumulative inertia interpretation percentage of the first two inertia was $p_2 = 58.2 < 75\%$, $q_2 = 59.7 < 75\%$, which can be seen from Table 4. 5. At this time, the convergence of the corresponding analysis model was poor, so it needs to be optimized.

3.4 Model convergence optimization

The optimization model proposed above was used to optimize, and the p_2' and Δp cycles corresponding to the month and the q_2' cycles and Δq cycles corresponding to the one-day time were calculated respectively.

Table 6 The calculation results of p_2' and Δp after the single month were eliminated one by one.

a	b	a	b	a	b
1	58	-0.18	7	69.7	11.52
2	58.5	0.32	8	60.3	2.12
3	59.7	1.52	9	61	2.82
4	60.6	2.42	10	59.9	1.72
5	72.8	14.62	11	53.1	-5.08

6	64	5.82	12	58.3	0.12

Table 7 The calculation results of q_2' and Δq after a single hour were eliminated one by one.

a	b	a	b	a	b
0	0.597	0.04	13	0.597	0.04
1	0.608	1.14	14	0.598	0.14
2	0.592	-0.46	15	0.595	-0.16
4	0.629	3.24	16	0.599	0.24
5	0.61	1.34	17	0.619	2.24
6	0.588	-0.86	18	0.595	-0.16
7	0.602	0.54	19	0.598	0.14
8	0.599	0.24	20	0.604	0.74
9	0.594	-0.26	21	0.577	-1.96
10	0.591	-0.56	22	0.583	-1.36
11	0.593	-0.36	23	0.603	0.64
12	0.594	-0.26	24	0.603	0.64

As can be seen from Tables 6 and 7, the Δp numbers corresponding to 5 minutes 6 and 7 in the month were relatively large, excluding these three months, forming a new contingency table of construction accidents and months. The Δq corresponding to 1, 3, 4, 6, 7, 16, 18, 19, 22, 23 in a day was relatively large. Excluding these periods, the corresponding data analysis of the cumulative model data of the first two columns of the combined chart formed by the new data was performed and the model was calculated.

The results showed that the cumulative time inertia coefficient explanation rate and the percentage value of the first two new contingency table models were $q_2 = 76.4\% > 75\%$ and $p_2 = 75.8\% > 75\%$, respectively. At this time, the convergence of the corresponding analysis model met the requirements, the result was more accurate, and the model was more robust.

4.4 Results and discussion of results

After optimizing the causes of building safety accidents, a two-dimensional correspondence analysis diagram was drawn based on the SP SS platform, as shown in Fig. 4 and Fig.5.

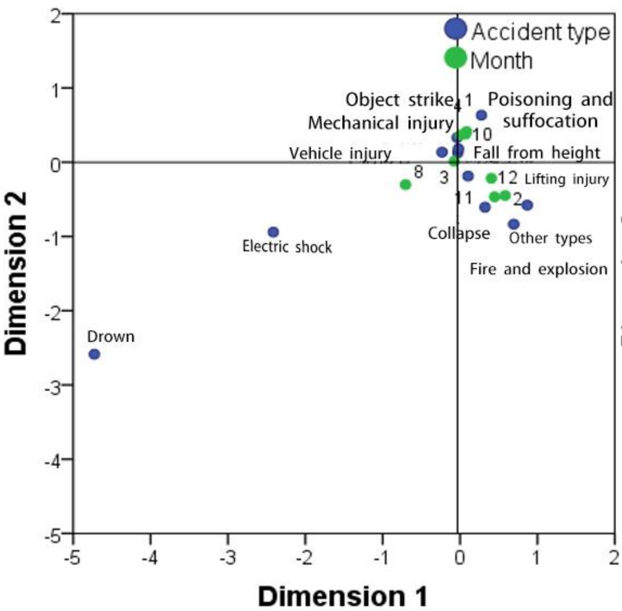

Fig. 4 Construction types and monthly

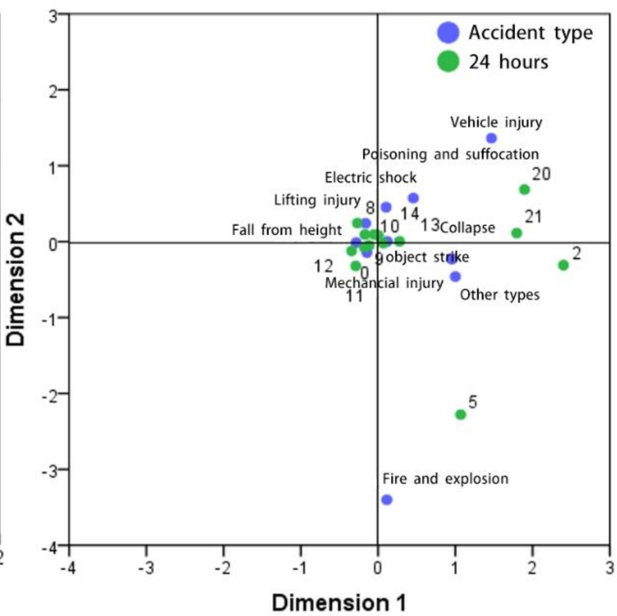

Fig. 5 Two-dimensional diagram of

As can be seen from Fig.4 and Fig.5, the accident cases and the months in which they occurred were mainly distributed in the first, second and fourth quadrants, and were more concentrated in（0,0）. Among them, the time from electric shock and drowning accident was August; fire and explosion were closest to February; poisoning and asphyxiation root was the closest in January. Therefore, it can be concluded that the occurrence of electric shock and drowning was closely related to August, fire and explosion were closely related to February, poisoning and asphyxiation were closely related to January. As can be seen from Fig.5, the accident cases and the specific time of occurrence were mainly distributed in the first, second and third quadrants, in which 5 was closest to fire and explosion, and vehicle injury was closest to 20. Therefore, it can be determined that 5: 00 in the morning was closely related to fire and explosion, and vehicle injury was closely related to 20: 00 in the evening.

Taking into account the macro situation of the construction industry during the period from 2012 to 2018, the construction accidents of 2012Mel 2018 increased by 11.4% year by year. According to the results, the corresponding measures were given: to avoid night construction as far as possible, to carry out construction in the environment with high temperature as far as possible, and to avoid construction in places with poor air circulation. To reduce the number of construction accidents.

5. Conclusion

According to crawling the data of 3896 building safety accidents from 2012 to 2018, this paper used the method based on a correspondence analysis model to mine the relationship between the causes of building safety accidents and the time of accidents and used the SPSS platform to mine. The results showed that the main occurrence of electric shock and drowning was closely related to August. Fire and explosion were closely related to February, while poisoning and asphyxiation were closely related to January. 5-6 a.m. was closely related to fires and explosions, and vehicle injuries were closely related to 8-9 p.m.

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